White Paper for the DOE Technical Review of the NPDGamma Experiment at LANL

(Updated September 28, 2004)

The NPDGamma Collaboration

October 6–9, 2004

1 Physics Motivation

The NPDGamma experiment will measure the parity-violating directional gamma-ray asymmetry A_γ with respect to the neutron spin when polarized neutrons capture on liquid para-hydrogen. A_γ is expected to be small $\sim -5 \times 10^{-8}$ based on the best estimate of Desplanques, Donoghue, and Holstein [1]. DDH describes the weak interaction between hadrons in terms of a meson-exchange potential with a strong interaction at one vertex and a weak interaction at the other. The potential has six unknown coupling strengths. The weak interactions of quarks are specified in the standard model. In order to calculate the hadronic weak couplings it is necessary to know the quark wave functions as well as the weak interactions of quarks. At present, it is not possible to calculate the couplings because theory of the interaction of quarks and gluons has not been solved at momentum transfers typical of nucleon-nucleon interactions in the nucleus. Knowledge of the couplings is important for at least three reasons. First, an over-determined set of experiments is needed to test whether or not the DDH potential does in fact describe the hadronic weak interaction. Second, knowledge of the couplings is necessary to describe and predict PV processes in nuclei such as PV asymmetries in scattering and decay and PV anapole moments. Third, a set of well-determined couplings provides a unique test of non-perturbative QCD. The weak hadronic couplings depend on quark-quark correlations in leading order because in order to interact weakly, the quarks must be at distances of order 0.002 fm.

The NPDGamma ($\vec{n} + p \to d + \gamma$) process is special in that A_γ depends only on the $\Delta I = 1$ pion coupling [2]. Although the asymmetry is small, there is no theoretical ambiguity because the two-nucleon wave functions are known precisely. The pion is the lightest meson and therefore carries the longest-range part of the hadronic weak interaction. The value of the coupling is controversial. The results of several experiments using ^{18}F have been interpreted by Haxton [3] to require a small value of f_π^1, while the anapole moment experiment in ^{133}Cs has been interpreted by Flambaum [4] to require a large value. The aim of the

NPDGamma experiment is to resolve the controversy by measuring f_π^1 in the two-nucleon system with a precision better than the statistical precision in ^{18}F.

2 The NPDGamma Experiment at LANSCE

The commissioned NPDGamma experiment with the cold neutron flux of the new flight path 12 at LANSCE can measure A_γ to an uncertainty of 5×10^{-8} in a year. This is four times better than the best published result. The ultimate goal is to measure this asymmetry to an accuracy of 10%. This is possible with sufficient beam flux and a carefully designed and built experiment. A detailed description of the NPDGamma experiment and the beam line can be found in the proposal "Measurement of the Parity-Violating Gamma Asymmetry A_γ in the Capture of Polarized Cold Neutrons by Para-Hydrogen," (appendix D).

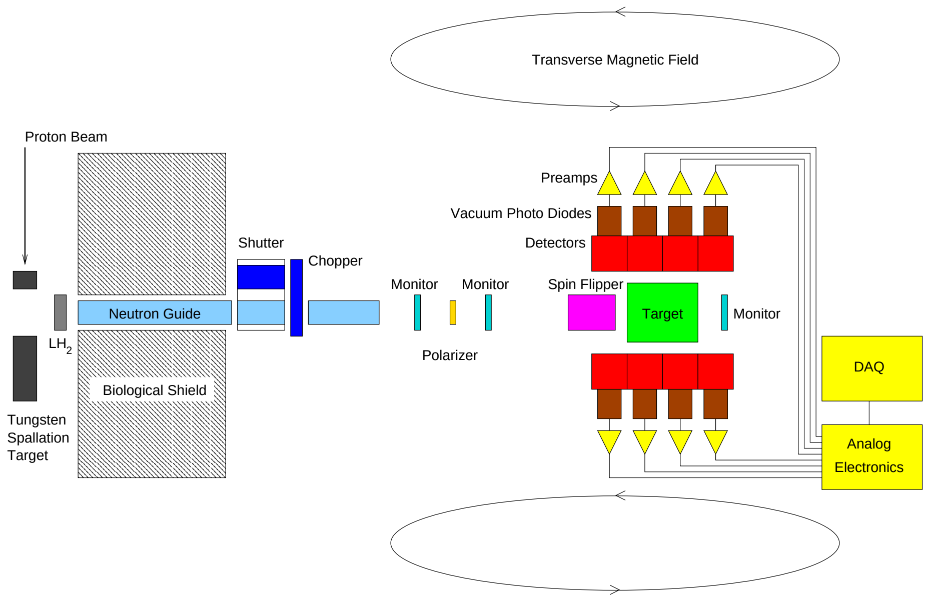

Figure 1: Diagram of the NPDGamma experiment, showing the major components.

3 Background of the Project

The NPDGamma Collaboration was formed and the proposal for the experiment written in 1997. The physics of the NPDGamma experiment was reviewed in 1997 by the Pendlebury Committee. In 1998 a technical review of the project was performed by the Spinka I Committee. The result of this review created the cost and schedule baselines for the project.

After the Spinka I Committee validations, the baseline budget and the schedule were presented to DOE. The scheduled completion date in the validated baseline was November 2001. In 1999 the project received its first DOE capital funds.

Following the Spinka I Committee, the project was divided into two projects: the construction of the NPDGamma experiment and the beam line. The estimated cost of the beam line was affected by changes at LANSCE. These included the LANSCE spallation neutron source becoming a Category III (CAT III) nuclear facility, the facility tightening its radiological shielding requirements, and the length of the beam line increasing to gain adequate floor space for the experiment. These changes increased the cost estimate of the beam line significantly. This elevated cost estimate triggered a new technical review — the Spinka II Committee — that took place in September 2000. The Spinka II review recommended that the NPDGamma project develop a written Project Plan and develop an improved cost estimate based on standard DOE contingency rates.

After the Spinka II review, the collaboration initiated preparation of the Project Management Plan (PMP) as well as the validation of the cost and schedule for the construction of the experiment and the beam line. The new scheduled completion dates were December 2002 for the beam line and June 2003 for the experiment.

The goal of the PMP was to ensure that the NPDGamma project had:

- formal management in place,
- reliable cost, schedule and contingency,
- management control in place, and
- appropriate reporting in place,

and that the project meets:

- its design specifications,
- relevant Laboratory ES&H requirements, and
- relevant Laboratory Quality Assurance requirements.

On November 5–6, 2002 the latest DOE technical progress review, Spinka III, was held. The collaboration's response to the findings of the Spinka III review can be found in section 4.

The first phase of the beam line commissioning took place in January 2003. The installation of the last part of the neutron guide was completed in March 2003 and the final commissioning of the beam line was performed in February 2004 after the experimental cave was completed, allowing the collaboration to operate the flight path. This completed the beam line project. The commissioning of the experiment, with the exception of the liquid hydrogen target, was completed on April 22, 2004.

4 Issues Identified by Spinka III Review and Collaboration Responses

This chapter is the collaboration response to the Spinka III review findings. The response letter was sent to DOE and the Committee. At the end of each section we have appended additional material to update our original response in light of recent progress on the experiment.

The Collaboration Response

The NPDGamma collaboration would like to thank the DOE, NSF and members of the annual technical review committee for their careful consideration of our technical progress on the experiment. The committee's report makes many insightful comments and helpful suggestions for bringing the experiment to fruition, which the collaboration appreciates greatly. In most cases we have taken actions to implement the committee's recommendations. The following summarizes our response to the primary findings of the review committee and describes the actions we have taken to respond to the committee's observations and comments.

Science of the experiment

The aim of the experiment is to measure the weak pion-nucleon coupling constant in the simplest possible system by measuring the parity violating asymmetry in the $\vec{n} + p \to d + \gamma$ reaction to an accuracy of 10% of its predicted value. The science of the experiment remains compelling even with the projected loss of sensitivity. We note that the NPDGamma error bar is expected to be dominated by statistical and not systematic uncertainties. The 1997 Pendlebury report states "The proposers anticipate a factor of ten gain in precision by taking data at LANL which, even if it falls a factor of two short, still has a good chance to detect a definite asymmetry." The reviewers were concerned about the reported loss of the sensitivity. One of the main factors in the sensitivity estimation is the brightness of the source that was earlier estimated only by modeling. To have the sensitivity estimation on more solid ground, we measured the FP12 moderator brightness in January 2003. This is the first measurement ever done from the Lujan partially-coupled, upstream/back-scattering supercritical hydrogen moderator. These results also have importance for the future design of the spallation sources like SNS. The measured FP12 brightness is close to our estimations and will not change our run time estimates presented to the reviewers.

Additional Comments Results of the brightness measurement have been published [5]. During the commissioning run the measurement was repeated and the earlier observations were confirmed as also the neutron flux at the end of the guide was determined. See sections 5 and 8.5.

Interaction between project and LANSCE management

To execute our aggressive schedule for the completion of the construction and installation, we have instituted new communication channels between the project and the LANSCE Division. This is in addition to what was already in place according to the Project Management Plan. The NPDGamma schedule is part of the facility master schedule. We have weekly planning meetings with the personnel of the adjoining flight paths FP13 and FP11A, and we have weekly planning meetings with the Lujan experimental area manager. In addition, LANSCE has appointed a physicist as FP12 beamline responsible scientist to improve reporting to the LANSCE management.

Additional Comments The FP12 responsible scientist is Josh Long from LANSCE-3.

Schedule slippage

Significant schedule slippage has occurred. To keep the project on track, the NPDGamma executive committee is following closely the progress of the work packages. The monthly work package progress reports are absolutely mandatory. Special attention has been directed toward the sub-projects that are on the critical path. Strong focus has been given to the issue of interference between the components of the experiment. We have defined criteria for the components built by outside institutes before they can be shipped to LANL.

Residual magnet field from the FP11A superconducting magnet

There has been considerable progress on this issue since the review, although the problem is not yet resolved to our satisfaction. After the review we were asked to proceed to build magnetically light cave shielding, which should be completed by June 2003. A working group, chaired by Doug Fulton (P-23 Group Leader) was established and it is examining various passive and active magnetic shielding solutions for implementation in the longer term, beyond 2003. It was concluded that passive shielding around the source is too expensive and would hinder the FP11A experimental program. Passive shielding of FP12 cannot achieve the level of magnetic field reduction necessary for the experiment to operate. One of the limitations is the ER2 floor loading limits. Calculations and testing of active shielding on FP11A have been completed. An administrative solution for calendar year 2003 has been confirmed such that the beam time will be shared between the two flight paths. The aim is to have an acceptable technical solution for the coming years after 2003.

Additional Comments The active shielding has been built and tested. The conclusion has been that we still have the magnetic interference problem due to a residual field in the steel. See section 7.6.

Commissioning manager

We had been discussing the need for a commissioning manager within the collaboration, and the committee's suggestion in this area is one that we heartily endorse. We have decided that this responsibility should be jointly undertaken by two individuals, one permanently resident at LANL, and one from an outside group having a major stake in the experiment. This management solution benefits from in-house expertise and continuity while at the same time addressing the need for coordination and integration of the important contributions from off-site participants. Scott Wilburn will serve as the LANL member of the management team; the member from an off-site institution will be resident at LANL during the period of his/her tenure as a member of the commissioning team. Shelley Page will serve with Scott Wilburn when she is at LANL this summer (2003); others in the collaboration may be appointed to serve when they are resident at LANL for long periods during the commissioning phase of the NPDGamma experiment.

Future reviews and potential future use of the NPDGamma apparatus

The collaboration is strongly committed to pursuing the physics of NPDGamma. The collaboration is enthusiastic about potential future use of the apparatus in related experiments, such as $\vec{n} + d \rightarrow t + \gamma$. Coupled with high intensity beams such as will be available at the SNS, the NPDGamma apparatus could make a key contribution to a new generation of precision experiments that could uniquely determine the weak meson-nucleon coupling constants in few body systems.

Additional Comments These plans were prior to the Tribble Committee's recommendations [6] where the study of the hadronic weak interaction was identified as a research topic for the SNS nuclear physics beam line.

Approach to data analysis

The reviewers raised the issue of a blind analysis of the NPDGamma data to avoid systematic bias in the determination of the asymmetry. In our opinion a blind analysis is most appropriate when many systematic error correction parameters need to be tuned, and the results are sensitive to this parameter tuning. In the NPDGamma case, the experimental parameters to enter the analysis are the ^{3}He polarization and the measured asymmetry from the CsI array. The polarization will be measured, and its characteristic time-of-flight dependence will be used as a consistency check on the asymmetry data. Our analysis procedure will be thoroughly tested on the known asymmetry from chlorine targets; we will not make cuts based on the detector asymmetry values, and we will ensure that our result is not sensitive to the tuning of arbitrary data quality cuts and correction parameters.

Additional Comments We have learned a great deal in the analysis of data from the commissioning run that will aid in analysis of the NPDGamma data.

Staffing of data shifts

We agree that, at least initially, the need for dedicated manpower on shift will be high as the experiment is brought on-line and carefully commissioned. Based on experience gained from this period, we will determine the optimum staffing level for long-term running of the experiment and will assign shift responsibilities accordingly.

Additional Comments The recently completed several month long commissioning experiment has shown the collaboration what will be required to successfully run the NPDGamma experiment. See appendix A.

Graduate students

We agree that the NPDGamma experiment would benefit from additional graduate student involvement, and we feel that the experiment offers an exciting opportunity for young researchers as the basis of their M.Sc. or Ph.D. degrees. Since the review, additional graduate and summer undergraduate students have joined the project. We currently have four graduate students engaged in the project: M. Dabaghyan from UNH, M. Gericke from IU, C. Gillis from Manitoba, and R. Mahurin from UT.

Additional Comments In addition to the students listed above, the collaboration has new students: M. Mason (undergraduate) at UNH, J. Mei at IU, and M. Sharma and M. Kandes at Michigan.

Senior research staff

We are exploring ways to facilitate longer-term visits from senior researchers who are resident at other institutions. Sabbatical leaves and summer visits are being actively encouraged.

Additional Comments See appendix A.

Summary

The collaboration is pushing very hard to get the construction phase of the experiment completed as soon as possible and to start the installation and commissioning which will take several months. The beam time for the Lujan User Program is scheduled in the upcoming run cycle to be approximately 134 days total. Beam production is expected to resume in July and to last until March 2004. This long beam cycle will allow us to have a few months of data taking. We still have several hurdles to pass but we are convinced that with a focused effort of the collaboration we will be able to complete the construction, installation, and commissioning of the experiment in time.

Additional Comments The beam became available in the facility on July 28, 2003 and was switched off on April 21, 2004. The run cycle included a number of breaks. The FP12 cave was completed in February 2004 which enabled NPDGamma to open the shutter for the first time on February 12, 2004.

5 Summary of 2004 Commissioning Run

The NPDGamma commissioning run began on February 12, 2004 with the completion of FP12, and ended on April 21, 2004 with the end of the LANSCE run cycle. The run tested all components of the FP12 beamline and of the NPDGamma experimental apparatus, with the exception of the liquid hydrogen target. In addition, parity violation measurements were made for (n, γ) reactions on several materials used in the construction of the apparatus. All components performed better than expected, with only minor problems encountered.

The commissioning plan prepared in advance of the run specifically outlined commissioning tests for all major components:

- neutron guide system
- neutron beam chopper
- magnetic guide field system
- ^{3}He beam monitors
- ^{3}He polarizer
- RF spin flipper
- CsI detector array
- detector electronics
- data acquisition system
- detector array motion system.

All components in this list were successfully commissioned. Several materials used in the construction and shielding of the apparatus were identified as potential sources of systematic effects due to parity-violation in (n, γ) reactions. The following materials were selected for parity-violation measurements during the commissioning run: Al, Cu, and ^{6}Li-loaded shielding material. Parity-violation measurements were performed for all of these materials. Additionally, parity-violation measurements were performed using In, Cl, and B_4C targets. In the rest of this section, highlights of the commissioning run are summarized. In the sections that follow, more details on the commissioning of individual components are discussed.

The most important result of the commissioning run is that all components worked as expected. We were able to produce an intense, polarized beam of neutrons, suitable for parity-violation measurements. Beam diagnostic devices performed well, giving us important information on neutron beam intensity, polarization, and other properties. The data acquisition system functioned well, taking large amounts of data and allowing online analysis of the results.

Of particular significance was the performance of the detector array. We easily achieved neutron counting statistics with the current mode detectors. The detector noise was low enough that checks for systematic effects of electronic origin could be performed in a relatively short amount of time. These tests revealed no such effects at the few 10^{-9} level.

In addition to testing and commissioning the individual pieces, the apparatus as a whole was used for parity-violation measurements with six nuclear targets. In the case of Al, a statistical uncertainty at the 10^{-7} was obtained.

6 Summary of the Current Status of the Project

The beam line construction project has now been completed and after the successful commissioning, also the components of the experiment have been completed with the exception of the liquid hydrogen target. A work package is considered to be complete when it passes a successful commissioning. In many cases, the major delay in completion of a work package occurred because the final commissioning could be only performed with the neutron beam, available only after the cave construction was completed. Results of the commissioning are presented in individual work package status reports.

The experiment and beam line work packages are listed in tables 1 and 2, organized by work breakdown structure. Also shown are forecast and actual completion dates for each work package.

Figure 2 shows the experiment in the cave during the commissioning run.

7 Status of the NPDGamma Experiment Construction Project

7.1 WBS 1.1 — Signal Electronics

The signal electronics convert the anode currents of the vacuum photo diodes into voltages and process the signals before they are read by the data acquisition system. These functions are divided primarily into two sets of modules: preamplifiers located on the detectors and sum and difference amplifiers (SD amps), located in the DAQ station.

The preamplifiers must convert the photo currents into voltages without adding significant noise to the signals. They must have sufficient time response

WBS	Title	Leader	Additional Institutions	Completion Date Forecast	Completion Date Actual
1.1	Signal Elect.	Wilburn (LANL)		12/02	6/03
1.2	DAQ	Mitchell (LANL)	TRIUMF	12/02	6/03
1.3	Detector	Snow (IU)	KEK, LANL, Manitoba/TRIUMF	1/03	6/03
1.4	Polarizer	Chupp (Michigan)	NIST, LANL, UNH, Hamilton, Dayton	12/02	1/04
1.5	Spin Flipper	Wilburn (LANL)		12/02	2/04
1.6	Guide Field	Carlini (JLab)	UC Berkeley	11/02	1/04
1.7	LH_2 Target	Snow (IU)	LANL	6/03	
1.8	Beam Mon.	Page (Manitoba)	LANL	12/02	12/03
1.9	Cave	Wilburn (LANL)		11/02	1/04
1.10	ER2 Util.	Wilburn		10/02	2/04

Table 1: NPDGamma experiment work packages.

WBS	Title	Leader	Additional Institutions	Completion Date Forecast	Completion Date Actual
2.1	In-Pile	Bowman (LANL)		12/02	2/03
2.2	Shutter	Penttilä (LANL)		12/02	2/03
2.3	Chopper	Leuschner (IU)	LANL	12/02	2/04
2.4	Integrated Shielding	Penttilä (LANL)		2/02	2/03
2.5	Neutron Guide	Penttilä (LANL)		12/02	2/04
2.6	ER1 Util.	Wilburn (LANL)		12/01	6/02

Table 2: NPDGamma beam line work packages.

Figure 2: Photograph of the experimental apparatus used in the commissioning run, installed in the FP12 cave. The vacuum pipe of the neutron guide is on the left followed by the ^{3}He spin filter (blue box), the spin flipper, and the detector.

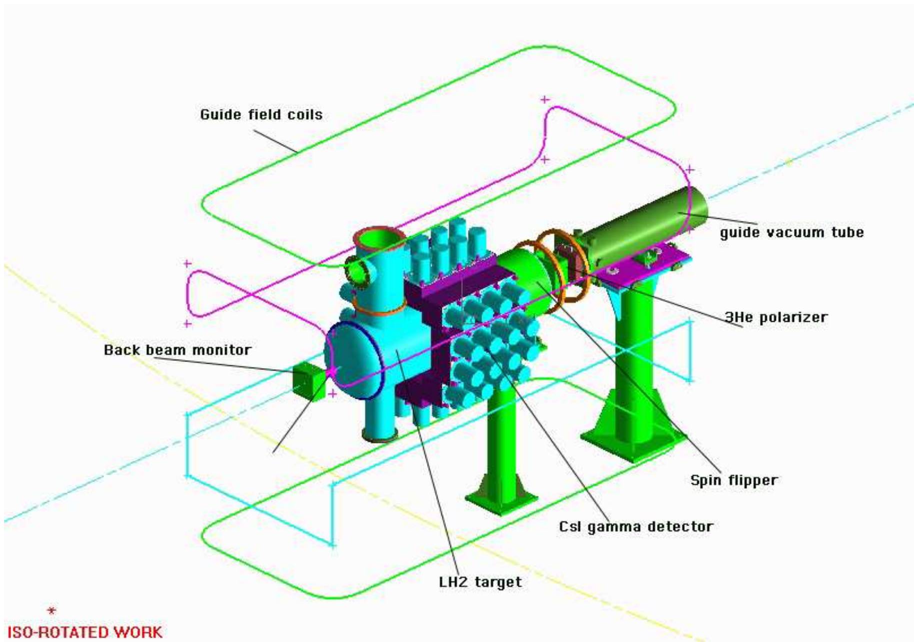

Figure 3: Perspective drawing of the NPDGamma experiment.

to record the changing gamma intensity over the course of each neutron pulse. Finally, the preamplifiers must be capable of driving output cables connecting them to the SD amps. Solid state preamplifiers were chosen instead of electron multipliers because of their insensitivity to magnetic fields. More about the characteristics of the preamplifiers can be found in reference [7]. The 48 CsI detectors are arranged in four rings of twelve. The signals from each ring go to an SD amp which sums the twelve signals to produce an average and then subtracts this average from the individual signals, providing twelve difference and one sum signal to the DAQ. This process removes common-mode variations from the individual signals, for example from neutron beam intensity changes. This effectively increases the resolution of the ADCs. The SD amps also pass the signals through 6-pole Bessel filters to limit the overall bandwidth and reduce the integrated noise.

Final versions of all components of the signal electronics were tested in the commissioning run. The devices performed as expected. The electronic noise was, as expected, dominated by the Johnson noise of the preamplifier feedback resistor for 43 of the 48 detectors (see detector section for further discussion). The SD amps produced the proper signals with the desired bandwidth without contributing measurable noise. We observed no evidence of any pickup of environmental noise by the electronics.

One of the most stringent tests of the signal electronics was a beam off measurement of the false asymmetry produced by spin-state-dependent electronic coupling, for example between the RF spin flipper and the detectors. In a 5 hour measurement with the neutron beam off and the spin flipper operating in its normal mode, we measured an asymmetry of $(1 \pm 3) \times 10^{-9}$. The result of this test conclusively demonstrates that no such systematic effects exist at this level.

No problems were found with the signal electronics that will require additional work, with the possible exception of the five noisy detectors. If the preamplifiers are found to be at fault, they will be repaired or replaced. The work package is complete.

7.2 WBS 1.2 — Data Processing

The data acquisition and processing are implemented in a VME-based system. The system has two desktop PCs and three stations with a VME crate, each of which has its own CPU. Each VME crate has a companion NIM crate for manipulating logic signals and operating gates for the various VME modules. The VME crate CPUs are coordinated by the two desktop PCs. All of the computers use a Linux operating system. The desktop PCs gather the data acquired by each crate and assemble it into run files, which are written to a large (3.5 TB) RAID disk array, and backed up on 190 GB removable hard disk drives. The DAQ system must reliably record detector data and companion data from the beam monitors and other systems in the experiment.

One of the VME stations is located outside the experimental cave, and it is responsible for gating the T_0's, and for data taken only once per pulse such as the proton current information from the accelerator. The other two stations are located inside the cave, and each has 48 channels of fast sampling 16-bit ADCs. The detector difference signals are sent to the second VME crate, which has no other inputs to prevent electrical noise pickup. The third crate reads the detector sum signals, as well as the beam monitor outputs and the spin flipper voltage and current. The vast majority of data ($> 99\%$) is the fast ADC data, since they sample a 16-bit value for each channel at up to 62.5 kHz.

In the commissioning run, over 1 terabyte of data was successfully taken. All data were backed up to removable hard drives as well. Online and offline analysis software allowed both system experts as well as the general collaboration to monitor the experiment subsystems and the quality of the data. Data acquisition failures and crashes were minimal and reduced in frequency by improvements (primarily in networking) made during the run. The most significant issue with the system was a jitter and drift in the function generators used to trigger the fast ADCs. This jitter and drift was at a level of less than 100 μs, and the detector data are written to disk in samples corresponding to 400 μs, so this should not affect analysis of parity violation data from the run. As a replacement for the bench-top function generators, two VME module pulsers have been ordered (one for each set of fast ADCs). The VME pulsers run on a 50 MHz clock and are stable to within a clock cycle.

Other remaining work with the data acquisition is to fully integrate other subsystems with slow data (polarizer, guide field, chopper, detector stand motion) into the data stream. A scheme using an ssh server on each system's control computer is being tested now and no difficulties are evident. Software development for both online monitoring and offline analysis is continuing.

7.3 WBS 1.3 — Detector

The NPDGamma detector is an array of 48 CsI(Tl) scintillators to detect 2.2 MeV gamma-rays from neutron capture in hydrogen. The size of a CsI crystal is $15 \times 15 \times 15$ cm^3. Scintillation light is converted to current by vacuum photo diodes (VPD) mounted on the crystals. Due to the high γ rates the detector array is operated in current mode. The current signals from the anodes of the VPDs are converted to voltages by low-noise analog electronics and then processed by VME based DAQ. The detector array is segmented longitudinally into four layers and azimuthally into 12 sectors and is tightly packed around the hydrogen target as shown in figure 4. Each detector module includes two LEDs for testing. An asymmetry in the integrated current of the upper and lower detector hemispheres is a signature of the parity-violating asymmetry in the $\vec{n}$+p $\rightarrow$ d+γ reaction assuming that false asymmetries are not present. CsI(Tl) scintillators were selected for their combination of good stopping power

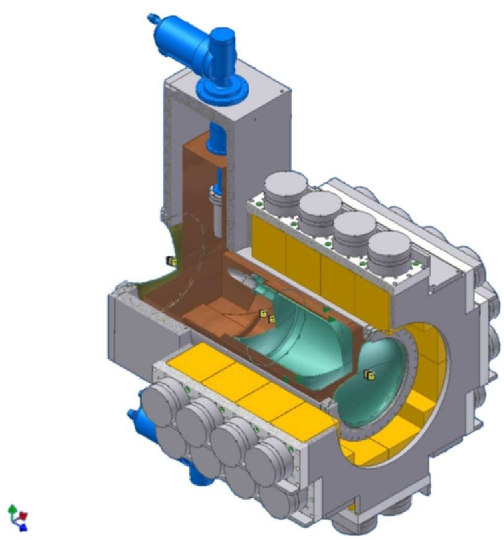

Figure 4: The CsI detector array, consisting of 48 individual detectors.

for 2.2 MeV gammas, high light output, acceptably low sensitivity to radiation damage, low magnetic field sensitivity, and cost. The VPDs were selected for their good sensitivity match to the scintillation spectrum of CsI(Tl), low noise, and insensitivity to magnetic fields. Other requirements were that the detector array must absorb most of the energy from a 2.2 MeV gamma, cover a solid angle of at least 75% of 4π, and possess an efficiency azimuthally uniform to a few % to suppress systematic effects. The array must have a high efficiency *i.e.* high scintillation and quantum efficiencies, and the preamplifiers have to be very low noise to achieve operation at the counting statistic limit. The array has to operate without introducing false asymmetries.

The most serious potential instrumental systematic effects are due to the radio frequency spin flipper (RFSF) [8], which is used to reverse the neutron spin. RF magnetic fields from the spin flipper or ambient EM fields may leak through the aluminum housing of the detector and affect the gain of the VPDs. If any change of the gain is correlated with the neutron spin state, a false asymmetry can be produced. The same is true for purely electronic signals which may couple to the detector electronics. The detector array and its electronics must therefore be insensitive to EM couplings.

To ensure that beam off measurements of these potential systematic effects can be performed in a short time compared to the time required to collect counting statistics, the number of photoelectrons produced in the VPD per MeV, is desired to be high (> 500). Operation at counting statistics relies both on good detector efficiency as well as excellent noise performance in the detector and DAQ electronics. The detector electronics have been designed to operate at a noise level close to the theoretical limit [7]. The efficiency enters into the calculation of the average photo current seen at the detector preamplifier output as well as the shot-noise seen at the VPD cathode. The time needed to measure a false asymmetry to a given accuracy is proportional to the inverse of the average photo-current. In current mode operation counting statistics is manifest as shot-noise seen at the cathode of the VPD.

The efficiency of the detector array was first simulated by EGS4 and then determined in various measurements. An average efficiency of 1300 photoelectrons per MeV was measured with radioactive sources. The detectors are efficient enough to ensure that beam-off false asymmetry measurements can be performed within a few hours and that the statistical accuracy of the beam-on measurements is dominated by gamma capture statistics. After the individual relative efficiencies of the CsI detectors and the VPDs had been measured, the components were matched and gains adjusted to produce an overall gain uniformity to $\sim 7\%$. Further adjustments in gain uniformity were made during the commissioning run using software adjustable gain modules in the DAQ.

The noise performance of the entire detector array and the DAQ have been measured during beam-off periods in the commissioning run (figure 5). While the overall noise performance of the array is more than sufficient to make the proposed measurements, there are five detectors that show noise levels that are close to a factor of two higher than expected. The noise of these detectors can be reduced to the typical level by further cleaning or repairing the preamplifiers. The measured noise shown in figure 5 also includes other backgrounds like cosmic rays and activation in the cave.

Long-term drifts in noise and pedestals have also been measured during beam-off periods [9] (figure 6). Using neutron capture on a boron target, which results in a single gamma ray per capture event, we confirmed during the commissioning run that the detector array operates at counting statistics [10], figure 7.

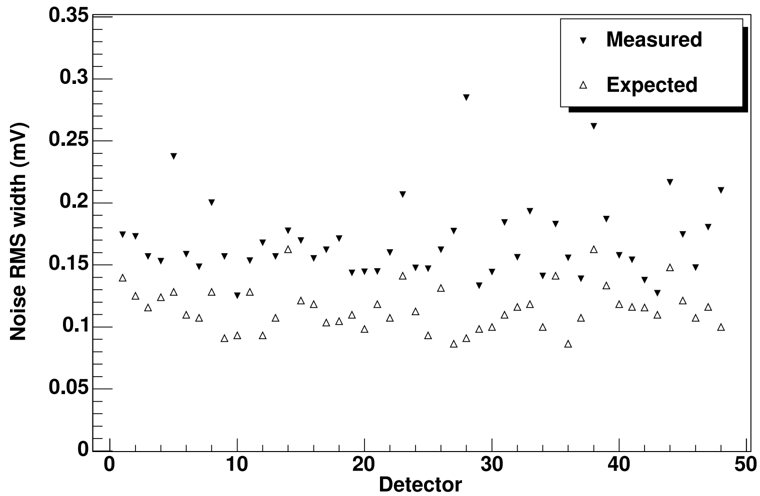

Figure 5: Calculated and measured noise levels for each detector. A 3 sigma cut was placed on the samples in the calculation of the RMS noise, to filter most of the cosmic background. The measured noise levels include contributions from any activation within the CsI crystals as well as ambient backgrounds.

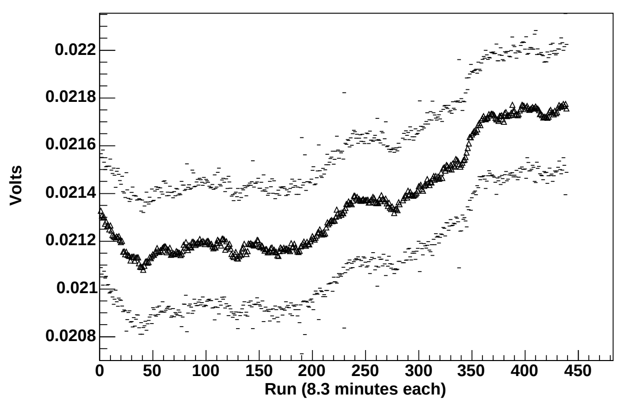

Figure 6: Long-term pedestal and noise drifts vs. run sequence for a typical detector. Each run is 8.3 minutes long. The center band indicates the mean of the run pedestal. The range of values between the bands above and below the mean give the RMS width of the noise.

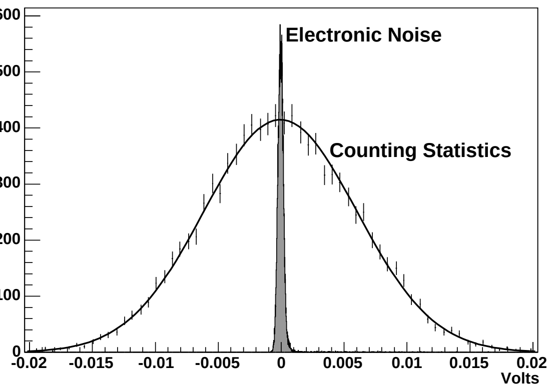

Figure 7: Results of the counting statistics analysis for a typical detector. The RMS width due to counting statistics is compared to the width obtained from pedestal runs (electronic noise). A fit to a "target in" data histogram with beam gives an RMS width of 6.1 ± 0.04 mV.

Measurements of the sensitivity of VPD gains to DC and RF magnetic fields found relative changes of 1×10^{-4}/G in a 10 G DC field or $1\times10^{-5}/\mathrm{G}^2$ for a 10 G AC field. These sensitivities are well below the expected variations of the fields at the detectors during the experiment. The array was tested for beam-off and beam-on (using LEDs as a source of light) false asymmetries due to electronic pickup and magnetic field induced gain changes. In each case asymmetries were measured to be zero at the 5×10^{-9} level in a few hours of running. Tests and results of these measurements are described in detail in reference [9].

During the commissioning run, the detector array was used to measure parity-violating gamma-ray asymmetries in Al, Cl, In, ^{7}Li, B_4C, and Cu. These nuclei are present in the cryostat materials, such as the Al vessel which will contribute about 10% of the total gamma ray signal in the detectors. It is important that these nuclei do not have non-zero gamma-ray asymmetries. Analysis of these data sets is currently in progress. A preliminary result of the Cl asymmetry is shown in figure 8.

Both absolute and relative signal intensities from each detector will be monitored throughout the experiment to verify detector stability and to maintain uniform gains. LED light will be used periodically to check in a short time for the presence of any false asymmetries from electronic pickup. Raw detector asymmetries will be formed for each 8-step spin flip sequence and appropriate selection criteria applied. Beam-off periods will be used to verify negligible afterglow and activation of the CsI.

A crucial issue for the experiment is the ability to determine the effective detector alignment, *in situ*, to within ± 20 mr with respect to the magnetic holding field direction, in order to suppress the contribution of a small parity-allowed

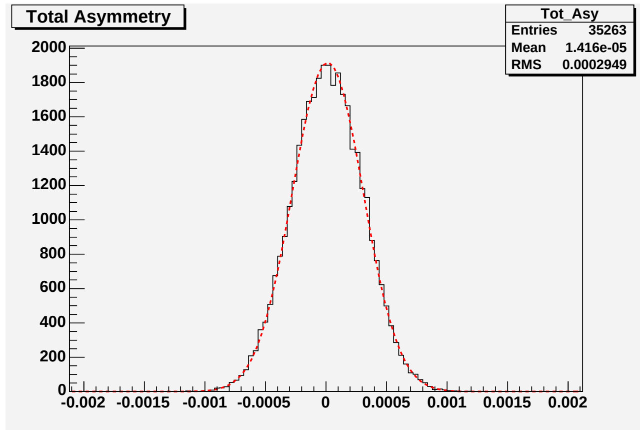

Figure 8: Preliminary result of the parity-violating Cl asymmetry. The Cl asymmetry was used as a diagnostic tool during the commissioning run. A preliminary value for the asymmetry is $(14\pm1.6)\times10^{-6}$ but it is not yet corrected for factors of order unity to account for the measured spin flip efficiency and for overall geometry.

left-right asymmetry to the parity-violating up-down asymmetry that we are seeking to measure. One possible approach for this determination was to calibrate the detector alignment *via* a capture reaction with a known and relatively large left-right gamma-ray asymmetry. Part of our test run in 2001 was spent searching for such asymmetries in several nuclei which had exhibited significant parity-violating up-down asymmetries, but no suitable candidates were found [8]. An alternative scheme based on scanning a neutron capture target up-down and left-right within the beam envelope was also explored during the 2001 test run, but this was found to be unsuitable due to non-uniformities in the beam intensity distribution. As a result, we have concluded that the preferred method to calibrate the detector alignment is to scan the entire detector array in up-down and left-right directions with the liquid hydrogen target in place. This approach places stringent requirements on the detector stand and safety of the hydrogen target.

A remote-controlled detector stand that can move weight of 1000 kg, was designed and built by the Manitoba/TRIUMF collaborators. The stand was tested during the commissioning run, using neutron capture on B_4C; data are currently being analyzed. The stand also provides mounting for the detector array and the RF spin flipper.

The successful commissioning of the detector completed the work package. We still need to understand the beam related backgrounds (about 10% of the signal) and how to shield the detector better. We also need to test the protective motion limits of the detector stand. This is important for the approval of the hydrogen target safety.

7.4 WBS 1.4 — Polarizer

In the commissioning run the cold neutron beam was polarized by a large-area laser-polarized ^{3}He spin filter. A laser-polarized ^{3}He cell was also used as an analyzer for diagnostics of the neutron beam and spin flipper. The spin filter operated for more than two months with steady over 45% polarization with minimal maintenance. *In situ* NMR diagnostics was used to measure and monitor ^{3}He polarization in the polarizer and analyzer cells. The analyzer cell was polarized off-line and moved to the experiment in a magnetic transporter.

Original Specifications

The original proposal called for a ^{3}He spin filter constructed of low neutron absorption glass cells, filled with an optimum density of ^{3}He gas, with ^{3}He polarization of 50% or more; the spin filter was to operate steadily for long periods of time (weeks to months). The spin filter cells were to be as large as practical in order to accommodate the large cross section (9.5×9.5 cm^2) of the FP12 neutron guide. The spin-filter system should also include calibrated NMR for diagnostic monitoring of the ^{3}He polarization and to flip the ^{3}He polarization with respect to the guide field.

The spin filter sub-system consists of five major components listed here with the institution responsible for its delivery of each:

1. the ^{3}He cells (NIST),
2. the oven and heating system (University of Dayton),
3. the NMR system for monitoring and flipping ^{3}He polarization (Hamilton College),
4. the lasers and optics (University of Michigan), and
5. the assembly and mechanical structures (University of Michigan).

The spin filter was assembled at the University of Michigan, and tested before shipment to Los Alamos in October 2003.

The spin filter cells, made at NIST, are state-of-the-art. The cells are roughly cylindrical, blown from molten, boron free, GE-180 glass. A number of cells have been made for the experiment, with characteristics given in table 3. They are 10 cm or greater in diameter and filled with about 1 atmosphere of ^{3}He (at standard temperature), a small amount of natural rubidium, and N_2 gas, which is necessary for optical pumping. Use of the cells in testing and commissioning has been conservative, with the best cells reserved for the 2005 data run.

Two commercial 30 W fiber-coupled laser-diode arrays pumped the cell top and bottom, so that the ^{3}He polarization was along the guide field.

The polarized ^{3}He analyzer was not specified in the original proposal, however it was added to tune and map the RF spin flipper and to provide a redundancy check of the polarization of the neutron beam. The analyzer will also be used to measure the polarization of neutrons transmitted though the liquid hydrogen target. This is accomplished with a cell that has a long polarization lifetime for off-line polarization and transportation of the cell to the experiment without significant polarization losses. The UNH collaborators assembled the polarization apparatus and magnetic transporter and provided the analyzer cell.

Actual Performance

The optimum ^{3}He thickness for the NPDGamma experiment on FP12 is about 5 bar-cm. The room-temperature cell polarization lifetime is an important parameter, because the maximum ^{3}He polarization generally improves with longer lifetimes as the Rb spin-exchange rate dominates the relaxation rate. The maximum observed ^{3}He polarization, P_3, improves with increased rubidium polarization resulting from more efficient coupling of the laser light to the cell and from longer lifetime cells.

Table 3: Cells made at NIST for the NPDGamma experiment.

Cell Name	Diameter (cm)	Volume (cm^3)	Thickness (bar-cm)	Lifetime (hours)	P_3 (%)
Astro	11.3	640	5.7	730	58
Pebbles	11.1	508	4.5	350	61
Dino	10.6	452	4.6	530	61
BooBoo	12.6	587	5.7	520	55
Yogi	10.6	432	4.4	185	
Kirk	10.5	624	5.8	600	
Rocky	13.4	773	4.7	150	
McCoy	9.7	470	7.3	470	66

The spin filter was installed in the FP12 cave in January 2004 and used then in the commissioning run. Over the entire period the spin filter showed steady operation with ^{3}He polarization generally greater than 45%. Figure 9 shows a record of polarization over four days for the cell "BooBoo" used in the commissioning run. In this cell the rubidium density at 165°C was found to provide the maximum ^{3}He NMR signal. The lasers were tuned to provide the maximum power at 794.7 nm. For the data of figure 9, the ^{3}He polarization was determined from the neutron transmission measurements [11]. The accurate and stable NMR measurement could provide a relative measure of the ^{3}He polarization that can be calibrated with the neutron transmission measurement.

The ^{3}He polarization of over 45% was maintained steadily over most of the two months of commissioning. However, polarization in figure 9 indicates a steady small decrease over the six day period. The reason for the loss of polarization has not yet been understood. The commissioning of the ^{3}He spin filter system completed the Polarizer work package.

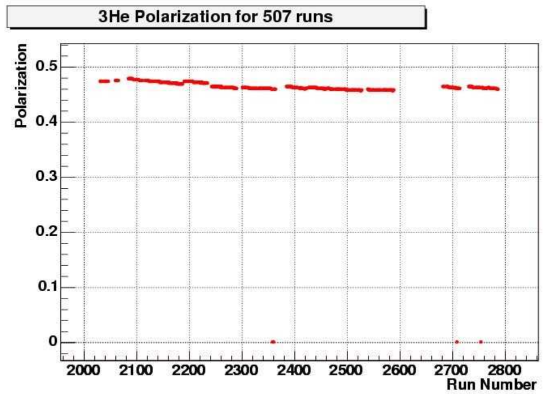

Figure 9: Polarization of the ^{3}He "BooBoo" as a function of time, measured during the commissioning run. The plot covers a time of approximately 4 days.

One of the three spin flips to control systematic errors of the experiment is the adiabatic fast passage flip of the ^{3}He spin. In the commissioning run the AFP spin flip did not work, only a part of ^{3}He spins flipped and this caused a big loss of polarization. Further studies are necessary to determine the cause and find a solution for the poor ^{3}He spin-flip performance.

Plans for the Improvements, Goals and Schedule

There are two priorities for improvements to the ^{3}He spin filter: 1) increase the polarization and figure of merit with a better cell and optimization of the magnetic environment, temperature, and lasers; 2) improve the ^{3}He AFP spin flip.

The NIST cells available for the experiment are listed in table 3. The cells "Dino" and "Pebbles" will be installed and studied this summer (2004). Once the cell is installed, we will study optimization using NMR. The calibration of the NMR changes from cell to cell, however, it provides an accurate relative measure of ^{3}He polarization. High and stable ^{3}He polarization is the highest priority. This work will be completed in the FP12 cave in October 2004.

Other issues that need to be addressed prior to the 2005 run are improved stability and calibration of the on-line NMR measurements of ^{3}He polarization and electrical isolation of some of the spin-filter control and safety systems.

During the 2005 run, analyzer cells will be used when diagnostics of the neutron polarization and spin flipper and recalibration of the ^{3}He NMR polarimetry are required. Optimal analyzer cells will be constructed at NIST, UNH, or Michigan.

The commissioning run completed this work package.

7.5 WBS 1.5 — Flipper

The spin flipper consists of an RF solenoid, with its axis oriented along the beam direction, perpendicular to the main (DC) magnetic field. When energized, the spin flipper applies an AC magnetic field which is perpendicular to the DC magnetic guide field. The combination of these two fields adiabatically rotates the neutron spins by π. The amplitude of the AC field must fall as $1/t$ during each neutron pulse to rotate neutrons of different energy by the appropriate angle, $\theta = \gamma B(t)\Delta t$ at resonance, where Δt is the time the neutron spends in the AC field. The spin flipper solenoid is contained in an aluminum can to contain the AC magnetic field.

The RF spin flipper was selected because the NPDGamma experiment is very sensitive to DC magnetic field gradients. Because the neutron beam is pulsed, spreading the arrival times according to time-of-flight, we can use a spin flipper with no DC field gradient and a time-varying AC amplitude.

The current profile needed for operating the spin flipper will be generated each beam pulse, and either sent to the solenoid or the dummy load by the spin sequencer. A feedback loop adjusts the output of the RF amplifier to achieve the desired profile. Current and voltage to the solenoid are continuously monitored to verify stable operation.

The AC magnetic field of the spin flipper was mapped in bench tests. The measured field values agree with calculations within 5%.

The final version of the spin flipper and all its components were successfully used in the commissioning run. Beam off measurements showed no false asymmetry due to coupling between the spin flipper and the detectors at the few times 10^{-9} level. Measurements of the spin flip efficiency were made and are currently being analyzed. Although a final result is not yet available, the efficiency appears to be high. This is consistent with an earlier test using a preliminary version of the spin flipper that measured an average spin flip efficiency of 97%.

A minor problem was observed with the arbitrary waveform generator used to generate the current profile. After several hours of operation, the timing of the waveform would shift, requiring manual reset of the device. A new arbitrary waveform generator with guaranteed timing accuracy has been ordered.

This work package is complete.

7.6 WBS 1.6 — Guide Field

The 10 G guide field is designed to transport neutron spin from the ^{3}He polarizer to the liquid hydrogen target. Requirements for the guide field are mainly determined by the polarizer's need for field homogeneity of better than 3 mG/cm and the need to suppress Stern-Gerlach steering of the neutron beam(0.1 G over the dimension of the apparatus). These translate into a homogeneity of the magnetic field and a field gradient of less than 1 mG/cm along the beam. The other design criteria for the guide field were current stability and field monitoring with milligauss resolution.

The guide coil system consists of 4 race-track coils in a double Helmholtz configuration, power supplies, a high precision field measurement system, and DAQ for field control and monitoring. The inside dimensions of the coils are $118.5'' \times 52.5''$. Figure 10 shows the guide coils during initial setup for commissioning in January 2004.

Figure 10: Guide coils in the cave with the detector stand. On the left is the neutron guide reaching inside the coils.

The current for the main coils is provided by a water-cooled DANFYSIK Magnet Power Supply 858 - System 8000 with 10 ppm guaranteed current stability. Two calibrated and aligned Bartington 3-axis flux-gate magnetometers (MAG-03), with 0.1 mG resolution, are used for field measurements and monitoring. These two flux-gates were mounted above and below the spin flipper during the commissioning run, and were used to monitor the guide field.

The system assembly and testing was completed at LBNL, Berkeley in April 2003. Then the system was moved to Los Alamos in June 2003. In January 2004 we installed the guide coils in the FP12 cave. We have performed several field measurements with the coils on and off [12]. Several cycles of measurement and current adjustment have been done to minimize the field gradients. The only equipment present during these measurements inside the coils was the detector stand. These measurements completed the guide coil work package in January 2004.

Figure 11 shows the measured ambient field in the cave with the coils off. The variations are due to remanence magnetization in the cave steel shield; the earth field should show up as a constant value and is largely shielded. Clearly, the cave shields to a certain extent against magnetic noise.

Figure 12 shows the field measured along the beam axis with the coils turned on. The 4 curves correspond to 2 flux-gate positions around the center of the beam axis, and 2 positions ± 12 cm off axis, within the interesting beam region.

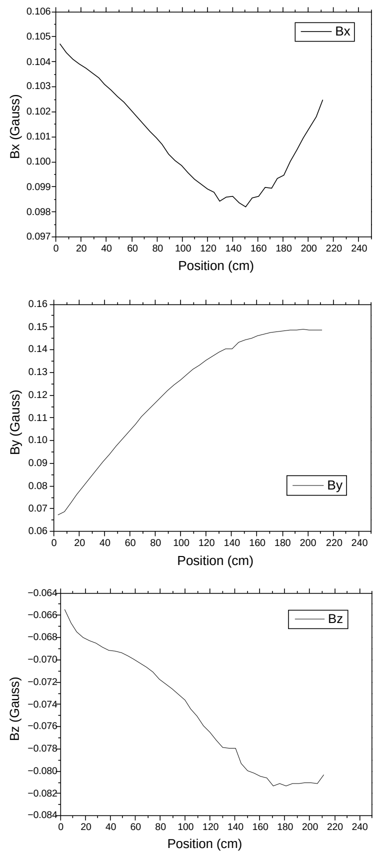

Figure 11: The three components of the ambient field measured inside the cave with the coils off. B_y is the vertical direction. The given position is along the beam axis with $y = 0$ at the front flange of the neutron guide.

For comparison, the black line in the B_y plot indicates a gradient of 1 mG/cm. The observed field values are changing very smoothly along the beam axis. A clear sharp rise is observable at $y = 0$, which is attributed to slight magnetization in the stainless steel vacuum jacket of the neutron guide.

The B_y component is within 1 mG/cm specifications along the full 200 cm along the beam path inside the coils. The B_z component, horizontally perpendicular to the beam, has unwanted structures and gradients larger than defined by specifications. Three spikes have been identified as caused by the detector table motor and steel rails. Several field scans perpendicular to the beam axis were done and field gradients of up to 3 mG/cm were observed for B_x and B_z. However, it was questioned if the alignment of the probe directions for these measurements was really accurate enough to allow these conclusions, or if the measured gradients should be rather interpreted as an upper bound.

With coils off one can clearly observe a relaxation of the steel of the cave walls, with 1.5 mG in 6 hours in B_y. B_x and B_z were observed to be stable below the 1 mG level. When the coil currents are switched on, we observed a slow change in B_x and B_z, which could be attributed to a slow magnetization (change below 1 mG in 6 hours). The stability of B_y is changing within 1.5 mG over 6 hours due to the changing magnetization of the cave.

The obtained homogeneity of the field along the beam axis is within specifications and therefore large improvements to the field are not required by the experiment. However, there are improvements planned, and the necessary preparations are under way:

- The code for optimizing the guide coil locations and applied currents has been updated to reflect the real dimensions of the experimental cave as observed after completion. Similar behavior was observed when switching the coil current on.

- In order to obtain a more accurate measurement in B_x and B_z, a new scan-device for mounting a flux-gate using a stepper motor with computer controlled movement is being developed at UC Berkeley. We hope to eliminate small probe misalignments between the measurements done perpendicular to the beam axis.

- If necessary, shim coils will be attached to the outside of the coil frame in the x and z directions to correct the observed small field gradients. This can be especially important to minimize the observed gradients in the polarizer volume. This has to to be done also with respect to the influence of the fringe field of the flight path 11A, discussed below. Shim coil effects will be calculated before physically putting the coils in place.

These improvements will be finished by October 2004.

The magnetic interference between FP11A and FP12

The FP11A-FP12 magnetic field interference working group has estimated effects of the 11 T magnet of FP11A on the FP12 cave through calculations and

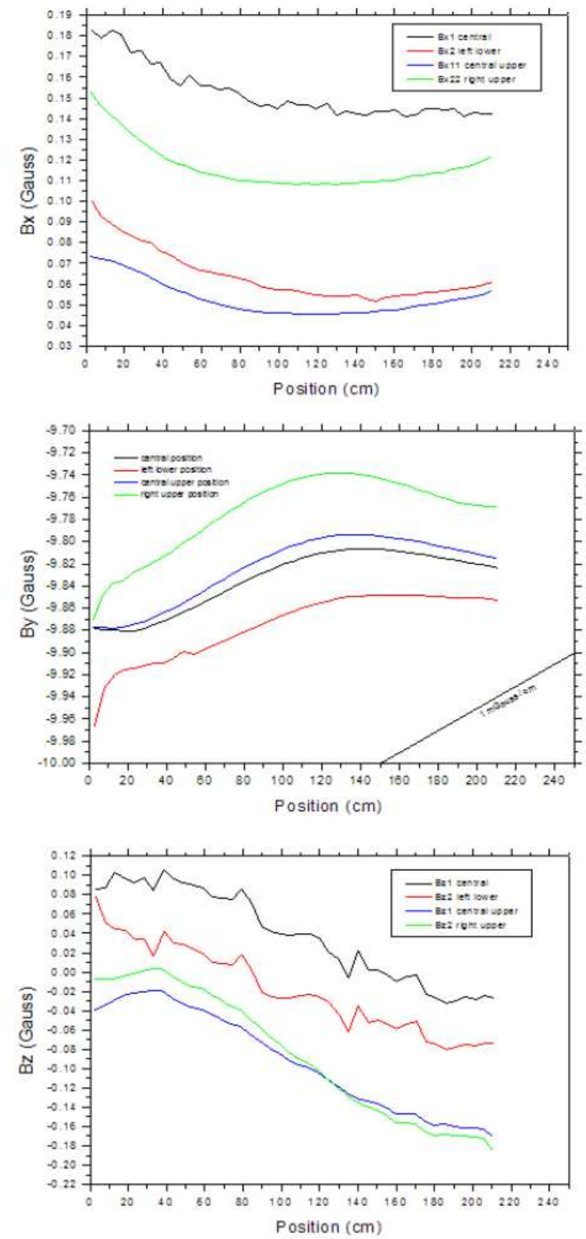

Figure 12: The three components of the guide field with the field probes in four different positions in the beam center and ~ 15 cm off the central axis on each side. The straight black line at the right-hand side of the B_y plot indicates a field gradient of 1 mG/cm. The given position is along the beam axis with $y = 0$ at the front flange of the neutron guide.

field measurements on the floor. To minimize effects on the NPDGamma experiment, an active shielding approach was selected where bucking coils were wrapped around the FP11A cave to cancel in FP12 the dipole field component of the 11 T magnet. Before the FP12 cave was built the bucking coils and 11 T magnet were run and the fields were measured in the location of the FP12 cave. A recommendation of the working group was that the fringing fields of the FP11A magnet inside the FP12 cave should be measured and a decision made based on these results of how to operate the two experiments. Either the fringing fields can be controlled and the two experiments run concurrently, or there has to be an administrative solution where the beam time is shared between the two experiments.

On June 9–11, 2004 the fringing field measurement was performed. Before June 09, 2004 the FP12 cave steel had only been exposed to the 10 G internal field.

Findings of the measurement are that the vertical field component at the location of the critical central region of the NPDGamma experiment, between the ^{3}He cell and the liquid hydrogen target, changed by about three hundred milligauss when the FP11A magnet was fully energized, with no current in the bucking coils. This change in the vertical field at a reference point location could be tuned to close to zero by adjusting the current in the horizontal bucking coils on FP11A. Measurements were done for a series of magnet field strengths up to 11 T. When the magnet was turned off, the vertical component of the ambient field in the critical central region had changed by about 40 mG due to magnetization of the iron shielding of the FP12 cave and/or other iron in the vicinity of the magnet. This residual magnetization was measured to decay with a time constant of 90 days. Field changes of the vertical component by 6 mG may seriously affect the reliability of the data for the NPDGamma experiment. The relationship between the field of the 11 T magnet and required current in the bucking coils to cancel the fringing field was observed to be nonlinear, making any field cancellations difficult.

The following proposal has been sent to LANSCE for the operation of the two experiments:

The NPDGamma Executive Committee has discussed the magnetic interference measurement results and proposes the following operational approach for the 2005 run cycle:

1. The NPDGamma experiment will take data during the full 2005 run cycle.

2. We request that the operation of the FP11A superconducting magnet be divided into two time blocks. The first block should be at the beginning of the run cycle, while the NPDGamma experiment is in tuning phase.

3. The total run time of the FP11A magnet shall not exceed 50% of the available beam time.

4. The NPDGamma experiment can meet its goal of $\sigma_{A_\gamma} = 5 \times 10^{-8}$ with 50% of beam time available in the full run cycle.

5. When the FP11A magnet is operated, FP11A staff will optimize the fields of the compensating coils in collaboration with the FP12 staff.

6. The NPDGamma collaboration will analyze the experimental data taken with the FP11A magnet on and recover as much of the data as possible.

This approach will guarantee that the NPDGamma experiment will meet its goals for the run cycle. NPDGamma will have two sets of data; only careful off-line analysis of the data set will indicate if the FP11A magnet on data can be used to determine the gamma-ray asymmetry.

7.7 WBS 1.7 — Target

The LH_2 target for the NPDGamma experiment consists of a refrigerator system to liquefy 20 l of hydrogen, convert to the para-hydrogen state, and maintain the hydrogen target continuously and safely at a temperature of 17 K and a pressure of 1 atm. The system consists of a cryostat with two mechanical refrigerators and the liquid hydrogen target vessel, a fill-vent tube which extends vertically outside the enclosure and a vent stack out of ER2, a hydrogen gas handling/purification/monitoring system, and a SLC control system to monitor the state of the target. The target has been designed and constructed and will be operated jointly by NPDGamma collaborators from Indiana University and Los Alamos. As discussed in the Memorandum of Understanding (MOU), Indiana University has the major responsibility for target design, construction, and non-LH_2 testing at Indiana and LANL has the main responsibility for target safety and the integration and final testing of the system at LANL.

The liquid hydrogen target for the NPDGamma experiment must satisfy the following requirements.

1. It must absorb $\sim 60\%$ of the polarized cold neutron beam flux without depolarizing the neutron beam before capture.

2. It must possess negligible attenuation for the 2.2 MeV gammas from neutron capture.

3. The statistical accuracy of the measurement cannot be compromised by extra noise due to density fluctuations in the target from bubbles or pressure/temperature fluctuations.

4. No parity violation is introduced by gammas produced by polarized slow neutron capture on target materials other than hydrogen.

5. The target materials near the beam and detectors must be nonmagnetic to avoid magnetic field gradients and systematic effects from circularly polarized gammas.

6. The target system must be safe and it must meet proper national and LANL codes.

These requirements set the design parameters of the target as follows.

1. The need to prevent neutron depolarization requires the target to consist of liquid para-hydrogen at a temperature of 17 K. A 30 cm diameter by 30 cm length target size is set by the $10 \times 10 \ \ \mathrm{cm}^2$ beam size, the FP12 neutron energy spectrum, and the neutron scattering and absorption cross sections in para-hydrogen.

2. The target and vacuum system is made mostly of thin-walled aluminum and copper.

3. The target is superheated with a heater on the exhaust line of the target which can maintain the pressure in the (recirculating) target chamber at a value above local atmospheric pressure. This is also required for hydrogen safety.

4. The window materials seen by the incoming neutron beam are aluminum alloy and the remainder of the target chamber is protected from polarized neutron capture by a ^{6}Li-rich plastic neutron shield outside of the target flask.

5. Aluminum, copper, and G-10 plastic are the main construction materials.

6. The target must be designed so that in any scenario there is no release of hydrogen into the experimental cave if either the main vacuum or the target flask fails. The liquid hydrogen in the target and the gaseous hydrogen system outside the cave must be protected from leaks, sparks, and any potential accumulation points for H_2 gas.

The LH_2 target work package is not complete. Target and gas handling system design, construction, fabrication, cryogenic tests, tests of accident scenarios without liquid hydrogen, and tests of individual components in the target and gas handling system were performed at IUCF by August 2003 when the system was shipped to Los Alamos. The system was reassembled in a shed outside of ER2 where during fall 2003 and spring 2004 the cryostat instrumentation was mounted and tested, testing of the gas handling system was completed, and the SLC monitoring system was programmed and tested. Photographs of the target and gas handling system can be seen in figures 13 and 14. The NPDGamma commissioning run was used to verify that the target materials seen by the neutron beam possess negligible parity-odd gamma asymmetries.

Our plan is to first run the target with hydrogen in the shed and then move the target to the cave. We need full approval for hydrogen operation in the shed but the requirements for the shed operation are not as stringent as they are in ER2, where the target will be operated next to a Category III nuclear facility. The main milestones for the completion of the target work package are listed in table 4.

Figure 13: Photograph of the LH_2 target, assembled in the test shed.

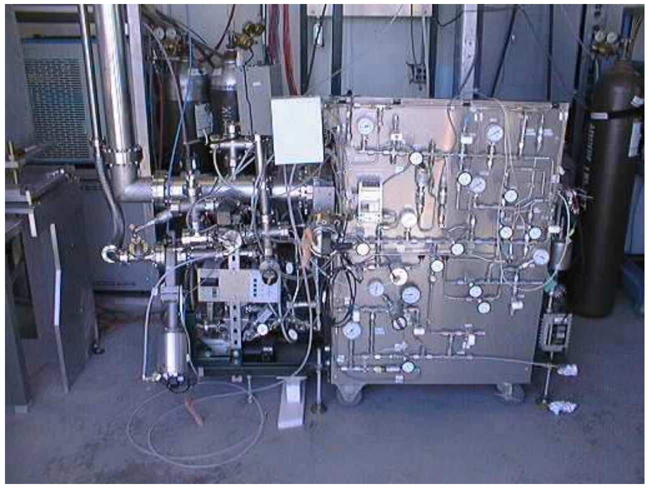

Figure 14: Photograph of the LH_2 gas handling system, assembled in the test shed.

LH_2 Target Safety

The target hydrogen safety has been our concern from the beginning of the project. We have had two safety reviews for the target design. The reviewers were charged by LANSCE. On May 10, 1999 we had a preliminary conceptual design review and on December 4–5, 2001 we had a review of the basic target design. The last review also created a design change process. These reviews enabled us to complete the fabrication drawings and to initiate fabrication of the LH_2 vessel, cryostat, and gas handling system.

The target requires a properly dimensioned relief line for discharging safely about 20 l of liquid hydrogen. When the LH_2 target is operated in ER2, the required pipe will be 6″ in diameter and will need to be about 100 foot long in order to extend outside of ER2. The gas handling system has to be in a ventilated enclosure to meet national electrical safety code for hydrogen operation. The ventilation line from the enclosure has also to end outside ER2. At present, we are working with hydrogen, structural engineering, and other appropriate approvals for the relief and vent lines.

We provide information in the form of drawings, design criteria, procedures *etc.* to the Hydrogen Target Safety Committee which is strengthened by local safety people. This committee will first review the target and related issues in the shed. Successful review will allow us to operate the target with hydrogen. This committee will also advise us on hydrogen safety for ER2 operation. Before we can work with hydrogen in ER2 and cave, the committee is required to review again the target installation. Before being allowed to operate the filled LH_2 target together with the rest of the experiment, LANSCE has to organize an experiment readiness review.

1.	LH_2 target operation in shed:	
1.1	Approved hardware in place	9/24/04
1.2	Safety and readiness review	9/30/04
1.3	LH_2 testing in shed complete	10/29/04
2.	LH_2 target operation in ER2:	
2.1	Design for relief and vent lines complete	8/20/04
2.2	Approvals for construction	8/31/04
2.3	Fabrication complete	9/30/04
2.4	Vent line installation complete	10/13/04
2.5	Design for new GHS complete	8/31/04
2.6	Design approved	9/15/04
2.7	GHS construction complete	11/01/04
2.8	Design for piping from target to GHS complete	9/17/04
2.9	Piping fabrication complete	10/8/04
2.10	Piping in place	10/25/04
3.	Move Target to cave:	
3.1	Target moved from shed to cave	11/19/04
3.2	Lines connected and everything checked	11/30/04
3.3	LH_2 safety review	11/22/04
4.	Target testing:	
4.1	Target cryo testing done (no LH_2)	12/17/04
4.2	Testing with LH_2 done	12/31/04
5.	Target ready for beam	

Table 4: Major milestones for completing the LH_2 Target work package. Note: these dates were established before the LANL shutdown. New dates for these milestones will be established when the schedule for full resumption of work is available.

7.8 WBS 1.8 — Beam Monitors

The experiment requires three neutron beam monitors. These devices are used to provide monitoring of the incident neutron flux, polarization of the neutron beam, ortho-para ratio in the liquid hydrogen target, and performance of the spin flipper.

The design of the monitors is based on a parallel plate ionization chamber filled with a gas mix consisting of ^{3}He, ^{4}He, and N_2. The active area of 12×12 cm^2 covers the cross section of the beam. The monitors — ^{3}He ion chambers — were built and delivered by LND, Inc. in January 2003. In November 2003 the monitors and their preamplifiers were tested on FP5 for the first time with neutrons. Test results showed that the monitors and electronics provide a low-noise current signal which is proportional to the neutron beam intensity, operating at neutron counting statistics. The time response is 100 μs, set in the preamplifier, when operated at -5 kV. This time resolution is enough for an accurate measurement of the neutron time-of-flight spectrum as can be seen in figure 17 of section 8.3 where a typical monitor time-of-flight signal obtained with a thin (intercepting only a few percent of beam) upstream monitor is shown, see also reference [11]. The monitor sensitivity to gamma-rays is negligible. We have converted the monitor current signals to provide a measurement of the neutron flux. The calculated spectrum is in agreement with the flux measurement with a ^{6}Li scintillator described in section 8.5.

The first thin monitor is mounted on the vacuum window at the end of the neutron guide. The second monitor, which is identical to the first, is installed between the ^{3}He spin filter and the spin flipper. Together, these two monitors measure the neutron beam polarization through a transmission measurement.

The third monitor will be mounted behind the liquid hydrogen target to monitor the ortho-para ratio of the liquid hydrogen. In addition, it can be used in conjunction with a ^{3}He analyzer cell to study the spin flipper efficiency. This monitor is thick, black for neutron energies of our interest.

During the commissioning run the monitors functioned as expected. The analysis of the data has showed that monitor pedestals are not stable and that they have time dependence. These effects are very small but have to be understood.

For the 2005 run we need to build a few preamplifier boards to have spares as well to fix minor problems on the existing boards.

This work package is complete.

7.9 WBS 1.9 — Cave

The cave work package consists of different shielding structures in ER2 — the guide tunnel, experimental cave, and beam stop. This shielding is required to protect personnel from radiation. The facility requirement for the dose levels outside the radiological shielding in ER2 is 1 mrem/hr. Our radiological shield is designed for 200 μA proton current; typically the facility runs with 100–130 μA. The steel part of the cave shielding serves also as electromagnetic shielding for the experiment. The beam stop was built in January 2003, the guide tunnel was completed in March 2003, and the cave in February 2004. Figure 15 shows a view of the FP12 cave site.

Figure 15: Photograph of the FP12 cave.

This work package is complete.

7.10 WBS 1.10 — ER2 Utilities

Utilities for ER2 consist primarily of electrical power. Since this is a new beam line, no such utilities existed previously and power at 480 V was brought from the main electrical room, converted to the appropriate voltages, and distributed to the branch circuits.

Four transformers are used to convert the incoming 480 V power to 208 and 120 V power for the experiment. Two transformers provide power to equipment located outside the cave, providing separate clean (15 kVA and dirty (30 kVA) power. Two 15 kVA transformers provide a similar system for powering equipment inside the cave. All four transformers feed breaker panels that supply the branch circuits.

Other utilities include compressed air, cooling water, and air conditioning for the interior of the cave. Compressed air and cooling water needs are minimal, and are served through existing supplies. The air conditioning system consists of a compressor unit located outside the cave, and two evaporator units located inside the cave. For the commissioning run, electrical wiring connected the evaporators to the compressor used to power the air conditioning system. Upgraded wiring, which uses fiber optic isolation to convey the demand signals from the evaporators to the compressor, is being installed now. This upgrade will eliminate a possible path for electrical noise to enter the cave.

All electrical work is complete, with the exception of the air conditioning wiring upgrade (currently underway). All other utilities are complete

8 Status of the NPDGamma Beam Line Construction Project

The NPDGamma collaboration was also responsible for building the new cold neutron beam line for the experiment. The flight path 12 at the Manuel Lujan Neutron Scattering Center was allocated for the NPDGamma experiment, and the agreement between LANSCE and Physics Division was covered by an MOU. When we started, FP12 consisted of only a core drilled hole in the biological shield viewing the new upper tier cold hydrogen moderator of the LANSCE spallation source. The work package consisted of installation of a neutron guide from the moderator to the experiment, construction of an external shutter (outside the biological shielding), construction of a frame definition chopper, and the radiological shielding around the beam line in ER1.

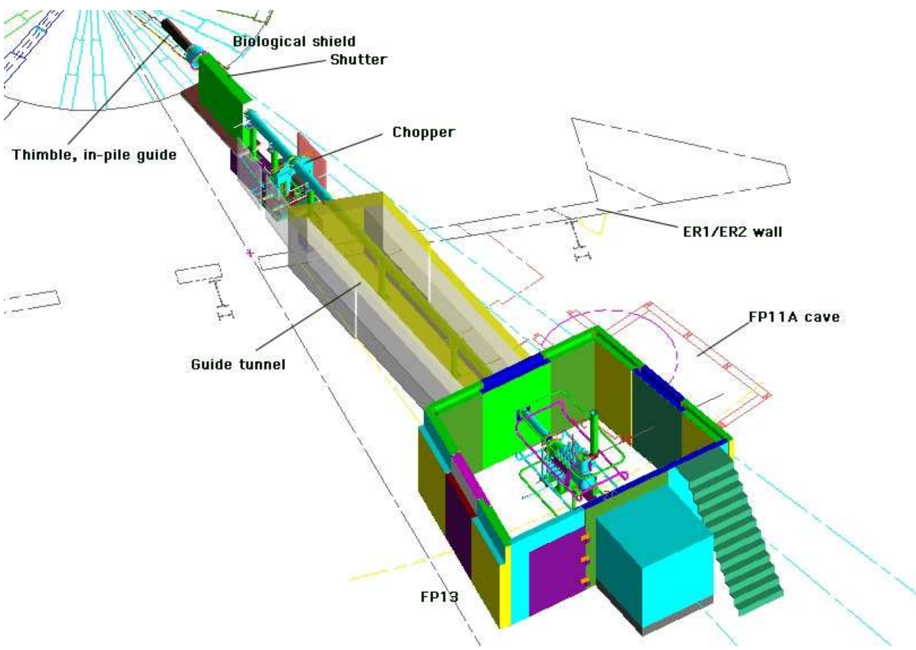

Figure 16: Perspective drawing of flight path 12 and the NPDGamma experiment.

Simultaneous with the flight path 12 construction, the adjoining flight path 13 was built by the LANSCE Division. The construction of these two beam lines was a collaborative effort between Physics and LANSCE Divisions coordinated by LANSCE. This integrated construction approach was one of the recommendations of the Spinka I Committee. The goal of the collaborative effort has been to save resources, since many of the beam line components are the same and also the front end of these beam lines had to be integrated because of the lack of space between the beam lines.

The schedule of the beam line construction had a strong dependence upon the facility schedule — most work could only be done when beam was off, *i.e.* when the facility had its maintenance breaks.

8.1 WBS 2.1 — In-Pile Guide

The in-pile part of the neutron guide system comprises the 4 m long guide, the steel insert that supports the guide and also allows the guide alignment, and the thimble — a vacuum jacket — that isolates the spallation source vacuum from the guide vacuum.

The largest guide that could fit into the existing hole in the biological shield has a cross section of 9.5×9.5 cm^2. This size of the guide is only possible if the section, about 2 m, of the guide next to the source is cantilevered. The mechanical strength of the thimble had to meet nuclear facility category III requirements. The thimble had to be built to fit precisely into the existing FP12 liner inside the bulk shield. Inside the thimble is a steel insert that cantilevers 2 m out of 4 m of the super mirror neutron guide.

The super mirror coating of the in-pile guide must provide a reflectivity of $\Theta_c = 3\times^{\mathrm{nat}}$Ni. The coating and the glass substrate must survive in the radiation field of the spallation source. The radiation from the source should not deposit so much energy on the guide as to cause diffusion of the coating layers and a loss of reflectivity. Finally, the guide has to hold its precision alignment for years.

The reflectivity of the coatings has been measured in a neutron beam by the manufacturer and in January 2003 we commissioned the ER1 neutron guide section. Results confirmed that the guide met the specifications. These measurements were done with techniques that we have developed to measure the moderator brightness and the guide performance. For more details and results see reference [5].

8.2 WBS 2.2 — Shutter

There is no room for a shutter in the biological shield of FP12. Therefore, the first *external* shutter in the facility was designed and constructed. The shutter has to stop the beam when in the closed position so that personnel can work in the experiment. In the open position, the neutron guide section of the shutter has to align with the rest of the neutron guide. The shutter block is moved by a hydraulic system. The block is about 2 m long and weighs about 2.5 tons. The neutron guide is filled with ^{4}He gas. The shutter is part of the facility safety system.

The shutter was commissioned in January 2003.

8.3 WBS 2.3 — Chopper

For the analysis of gamma-asymmetry data, accurate knowledge of the neutron beam energy is required and is obtained through a time-of-flight measurement. This is possible since in the pulsed spallation source neutrons are created at the same moment, at LANSCE every 50 ms, but because of their energy distribution they arrive at the target at different times. The NPDGamma experiment is about 21 m from the moderator, which is long enough for neutrons from adjacent beam bursts to intermingle before they reach the experiment, thereby obscuring the time-of-flight information. In order to eliminate this frame overlap, the beam line is equipped with two rotating (1200 rpm) frame-definition choppers located at 9.3 m from the surface of the moderator. To block undesired neutrons, the chopper aluminum plates are coated with Gd_2O_3. The thickness of the absorber layer was determined by the requirement that it be black for neutrons with energies less than 30 meV. The diameter of the chopper plates is 1024 mm. Each chopper plate has a 109° aperture for neutrons; this aperture is fully open at 11 ms at the chopper location and at 25 ms at the NPDGamma detector location. It takes 1.8 ms for the edge of the beam aperture to cross the full guide. At 21 m from the neutron source the aperture opening or closing takes 4 ms as seen in figure 17

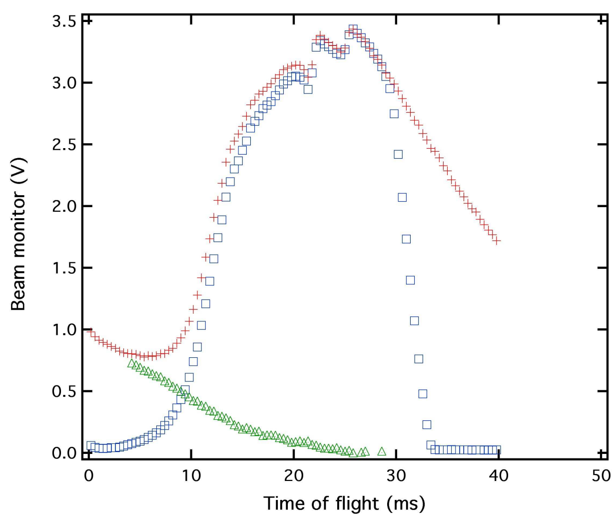

Figure 17: Time-of-flight spectra measured by a ^{3}He ion chamber at the end of the guide. The spectrum (crosses) is for neutrons with the chopper off and the spectrum (squares) for neutrons with the chopper on and phased to T_0. The spectrum (triangles) shows the contribution of slow neutrons from the previous frame when the chopper is not running.

The performance of the frame definition chopper is illustrated in figure 17, which shows time-of-flight spectra measured by the ^{3}He beam monitor mounted on the end of the neutron guide. A spectrum (crosses) was measured with the chopper off. Under these conditions, low-energy neutrons from the previous frame overlap with neutrons from the current frame. A spectrum (squares) was taken with the chopper running and phased to T_0. The beam aperture starts to open at 0 ms, is fully open at 4 ms, and starts to close at 30 ms. Note that the full length of the time-of-flight frame is 50 ms. The last 10 ms is used by the DAQ to transfer data. The fast neutron part of the spectrum was not detected because of the small $n{-}^3$He absorption cross section and the small ^{3}He thickness of the monitor. With two independent choppers any length of the time-of-flight period shorter than 26 ms can be selected. The choppers are tightly phased to the facility master-timing-reference which in turn is referenced to the power grid. The same timing is used for proton extraction from the PSR. The chopper feed-back loop keeps the chopper phased to T_0 with 50 μs accuracy. This is small compared to the data acquisition sampling interval of 0.4 ms.

The signal from the last 10 ms in the frame, when the neutron beam is completely blocked, is used to study detector pedestals and beta decay from neutron activation.

During the commissioning runs the chopper ran steadily but was found to lose its phase lock a few times due to noise in the chopper pick-up signal. New electronics is under construction to fix this problem.

The chopper system was installed in March 2003 and commissioned in February 2004.

8.4 WBS 2.4 — Integrated Shielding

The integrated shielding is a radiological shielding structure in ER1. It is comprised of layers of steel, regular polyethylene and borated polyethylene. Shielding efficiency, *i.e.* thickness of the shielding layers, is set by the dose limits given by the facility. The dose rate outside the shield must be less than 2 mrem/hr in ER1.

Because of the proximity of flight paths 11, 12, and 13 in ER1, it was necessary and cost effective to cover these beam lines with integrated shielding, instead of trying to build individual shielding packages around the beam lines.

In spring 2002 the integrated shielding was completed. However, a part of the shielding had to be opened in order to install the chopper and the last guide section.

8.5 WBS 2.5 — Neutron Guide

The total length of the FP12 super mirror $m = 3$ neutron guide is 21 m. The inner cross section is 9.5×9.5 cm^2. The guide system has four separate sections; in-pile, shutter, chopper, and ER2 section. The three first sections are coupled to form a single volume that is operated filled with ^{4}He gas. The last 12 m long section is under vacuum. This section was installed in March 2003.

The transmission of the guide is based on the total reflection of neutrons on the inner walls of the coated guide. The reflectivity of each 50 cm long guide element was measured with 4.27 Å neutrons by the manufacturer and they are found to be better than 85% for a glancing angle $m = 3$. At the beginning of the commissioning run we measured the reflectivity of the installed 21 m long guide with a two-pinhole collimator system [5]. Figure 18 shows the result of this measurement, the number of 3 meV (5.3 Å) neutrons when the detector-downstream pinhole system was moved up-down with respect to the beam axis. When this system is moved farther from the beam axis, neutrons have larger glancing angles in order to enter the detector and go through a number of reflections in the guide. The maximum number of reflections for a 3 meV neutron is six. Each peak in the plot represents a different number of reflections. This measurement and its results are described in reference [13]. According to the results the neutron guide met the specifications. This completed the Neutron Guide work package. Based on the result of the moderator brightness measurement [5], we calculated the neutron flux out of the full length of the guide. The flux is plotted in figure 19 as a function of neutron energy. The result has been confirmed with measurements during the commissioning run.

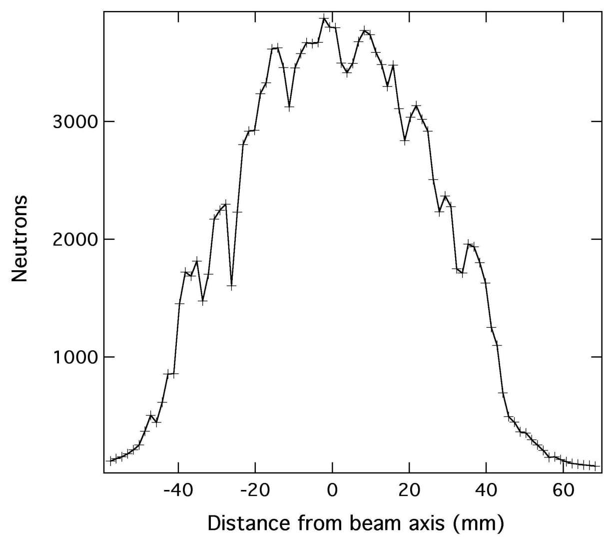

Figure 18: The number of 3 meV (5.2 Å) neutrons within a 2.4 ms gate width in 10 s when the two-pinhole collimator system was used to study the performance of the guide.

8.6 WBS 2.6 — ER1 Utilities

The ER1 utilities consist of 480 V three phase outlets for the chopper motors and 120 V outlets for the associated equipment, as well as shutter controls and vacuum equipment for the neutron guide. All ER1 utilities are complete.

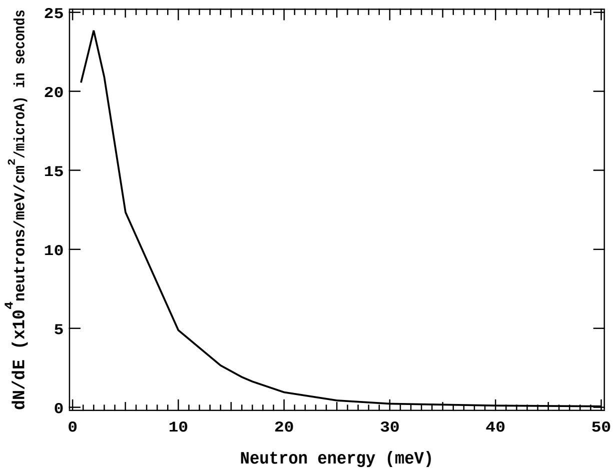

Figure 19: Neutron flux out of the FP12 guide as a function of neutron energy.

A Plan for the 2005 Run

A.1 Completion of the Experiment Construction Project

As discussed above, the completion of the LH_2 Target work package will complete the Experiment Construction Project. A schedule of milestones relevant to completing the LH_2 target is shown in table 4.

As discussed in the work package reports, the commissioning run has shown a need for minor improvements to the apparatus. Other tests will also have to be performed in order to determine if further modifications are required. These tasks have to be performed before the beam comes on and/or target activities start in the cave. A list of these tasks and completion dates is shown in table 5.

A.2 Operation Plan for the 2005 Running Schedule

A request to LANSCE management for running of NPDGamma during the 2005 run schedule is given in section 7.6 of this report. From the present until the end of the run cycle, activities for NPDGamma fall into three main categories:

1. preparations for the run, including installation and testing of the LH2 target in the cave;

2. initial data taking with the LH2 target, which will involve detailed systematic checks that the performance of the full apparatus is understood;

3. long term running to acquire the maximum statistics for the NPDGamma measurements during the 2005 running cycle.

2.3	Chopper modifications done	9/30/04
1.2	DAQ ready	9/30/04
1.3	Detector ready	9/30/04
1.3	Detector stand tested	7/29/04
1.4	Polarizer tuned	9/30/04
1.4	Analyzer ready	9/30/04
1.6	Guide field modifications done	9/30/04
1.7	LH2 Target:	
1.7.1	Hardware in place in shed	9/24/04
1.7.2	H2 safety review in shed	9/30/04
1.7.3	H2 testing in shed complete	10/29/04
1.7.4	Relief and vent lines in ER2 done	10/13/04
1.7.5	New GHS built	11/01/04
1.7.6	Target moved to cave	11/19/04
1.7.7	Target system assembled	11/24/04
1.7.8	H2 safety review	11/22/04
1.7.9	Target cryo testing done	12/17/04
1.7.10	Testing with H2 done	12/31/04
1.7.11	Experiment readiness review	12/23/04
	Experiment ready for beam	01/01/05

Table 5: Milestones that must be completed before the start of the 2005 run. Note: these dates were established before the LANL shutdown. New dates for these milestones will be established when the schedule for full resumption of work is available.

The tasks to be completed for category (1) operations are summarized in table 5. Work package leaders will be responsible for ensuring that adequate skilled manpower is on site at LANL to complete the necessary preparations for the experiment. During category (2) operations, data taking will be accomplished by shift crews assembled from the collaboration, with emphasis on participation of senior and experienced personnel and appropriate subsystem experts until the experiment is declared ready for long term production running. During category (3) operations, the requirements for shift manpower will be relaxed somewhat; an exact schedule remains to be worked out, but the Executive Committee has been working on developing a Shift Policy for the experiment which will ensure that adequate manpower is provided during all three phases of NPDGamma operations. The Shift Policy currently exists in draft form and remains to be officially endorsed at the next collaboration meeting, which is currently scheduled for September, 2004. We present the draft Shift Policy (proposed) here for consideration of the committee:

A.3 Draft NPDGamma Shift Policy (Proposed)

This proposed shift policy for NPDGamma is based on a model that has been successfully used for major experiments at Jefferson Laboratory. The policy is based on the principle that all collaboration members should contribute at least a minimum share of the required shift taking for the successful execution of the experiment. Furthermore, it is expected that senior personnel who have responsibility for major components of the experiment, along with system experts, will make every effort to support the initial phase when the liquid hydrogen target is being installed and commissioned in the cave, and when initial data taking and analysis with the hydrogen target is carried out. It is recognized that there may be exceptional circumstances that make it difficult or impossible for an individual to fulfill this exact shift taking requirement and that in such cases alternative forms of contribution may be considered.

After being approved by the collaboration, the NPDGamma Shift Policy will be implemented by a Scheduling Coordinator who is responsible to the Executive Committee. The Scheduling Coordinator will assign blocks of shifts to each institution with active collaborators on the NPDGamma Experiment. Each institution will have a Shift Coordinator who will assign individuals to the shift schedule in order to meet the institution's required shift quota. The shift schedule will be posted on the NPDGamma web site several weeks in advance of the run.

1. The Executive Committee will maintain a list of collaboration members who are active in the experiment and wish to qualify for authorship on the physics paper by meeting the requirements of the NPDGamma Shift Policy.

2. The total number of shifts to be manned per run will be divided by the number of authors expected to take shifts, in order to establish a shift

quota per individual. This quota is defined to be the minimum requirement.

3. The minimum requirement will be applied as an institutional average, allowing some flexibility to accommodate schedule conflicts and other constraints at the institutional level.

4. A schedule will be developed for each of the three main categories of activity as follows:

   (a) preparations for running, including installation and commissioning of the liquid hydrogen target in the cave;

   (b) initial data taking and commissioning with liquid hydrogen;

   (c) steady long term data taking to the end of the run.

   The number and degree of expertise of workers required in each of the three phases will be different, and will be established in consultation with the Executive Committee. During the preparations for running, it will be the responsibility of Work Package Leaders to ensure that adequate manpower is available at LANL to bring their systems to a state of readiness for beam. A shift schedule for phases (b) and (c) of the experiment will be arrived at in two iterations. Initially, the Scheduling Coordinator will assign blocks of time in 1-week intervals to the various institutions, with the number of weeks scaled to the institutional requirements and the times chosen to be optimized with the institutions' prime areas of responsibility. A spreadsheet will be circulated and posted on the web page showing the institutional blocks of shifts to be filled. Institutional Shift Coordinators will be at liberty to trade blocks of shifts with other institutions thereby resolving internal schedule conflicts provided that adequate expertise is maintained on-site during the more demanding first and second phases of the run as outlined above. Within an institutional block, individuals will be assigned to 8-hour shifts on a daily basis to meet the institution's quota.

5. Minor variations from the institutional quota will be allowed (at about the 10% level) if it is clearly demonstrated for valid reasons that an institution cannot meet its quota. It is recognized that greater flexibility may be needed with smaller institutions; schedule conflicts at this level will be resolved by the Scheduling Coordinator in consultation with the Executive Committee.

6. In the event that a scheduled shift is been canceled, *e.g.* due to accelerator failure, the time will be credited toward an individual's quota for having committed to take the shift. If the shift cancellation(s) leads to an additional block of time at the end of the run, the additional time will be scheduled according to the same procedure as above.

B Project Management and Costs

Management of the NPDGamma construction project is governed by the "$\vec{n} + p \to d + \gamma$ Project Management Plan for Experiment and Beam Line Construction" (PMP) (appendix B). The PMP is signed by the LANL management and the members of the Executive Committee of the NPDGamma collaboration. The Plan provides the baseline and controls that the NPDGamma collaboration, the NPDGamma management, and the LANL management have followed. The PMP describes the management structure, sets the rules and gives the work breakdown structure (WBS) that is the basis for the cost structure and schedule organization. The basic management elements of the project are 16 Work Packages listed in tables 1 and 2.

The PMP gives the cost and schedule baselines, major milestones, and budget profiles. The main management tools have been controls and reporting. The controls are:

- Management control
- Technical control
- Cost and schedule control
- Performance control
- Contingency management

Reporting has been the main element in following the progress of the project. The work package leaders have been responsible monthly to provide status reports to the Project Manager who then reports to the LANL management and compiles the quarterly report to DOE.

The Spokesperson has the overall responsibility for planning and execution of the project. The Executive Committee assists him to manage the project. The Project Manager is responsible for the overall management of the project. Collaboration meeting posses the highest authority in collaboration issues.

B.1 Beam Line Construction

The last phase of the commissioning of the beam line took place in February 2004. Results of the measurements showed that neutron guide, shutter, chopper, and radiological shielding meet the specifications. This completes the beam line construction project.

Table 6 shows base cost, contingencies, costed and committed for the beam line construction.

B.2 Experiment Construction

The successful commissioning run in February – April, 2004 completed the experiment construction work packages with the exception of the LH_2 target. The

WBS	Element	Base Cost	Conting.	Costed and Committed
1.1	In-Pile	82	21	103
1.2	Shutter	159	44	203
1.3	Chopper	87	11	98
1.4	Int.Shield.	477	133	610
1.5	Guide	750	51	801
1.7	ER1 Util..	49	22	71
1.9	Commis.	14	7	21
	Total			1907

Table 6: Base cost, contingencies, and costed and committed for the beam line work packages.

LH_2 Target work package status report (section 7.7 and in table 5 give the path with major milestones to the completion of the work package. The target system is complete when the target is commissioned cryogenically in the cave with hydrogen and we have observed gamma-rays from the $p(n,\gamma)d$ reaction.

Table 7 shows base cost, contingencies, costed and committed, and available contingency for the experiment construction project.

WBS	Element	Base Cost	Conting.	Costed and Committed	Available Conting.
1.1	Signal Elect.	40	11	51	0
1.2	DAQ	72	6	78	0
1.3	Detector	161	12	173	0
1.4	Polarizer	17	3	20	0
1.5	Spin Flipper	18	6	24	0
1.7	LH_2 Target	88	30	118	0
1.9	Cave	544	184	707	21
1.10	ER2 Util.	93	14	107	0
1.11	Commis.	11	6	13	4
	Total			1291	25

Table 7: Base cost, contingencies, and costed and committed for the experiment work packages.

C Proposed Move of NPDGamma to HFIR

Installation of the NPDGamma experiment at ORNL's High Flux Isotope Reactor (HFIR) will allow the experiment to attain its goal of measuring f_π^1 with an error smaller than from the ^{18}F experiments. This goal cannot be reached at LANSCE on FP12 in three years of running. The limitations at LANSCE were discussed in the Fall 2002 DOE Technical Review. On August 12, 2003 the NPDGamma Executive Committee sent a letter to DOE, NSF, and ORNL requesting that the agencies consider moving the NPDGamma to HFIR at ORNL where the experiment could reach its goal in a calender year of running, after an initial measurement of A_γ at LANSCE that would determine f_π^1 four times better than the best existing measurement [14].

> *The experiment will then be poised to take a first 1000 hour data run at the beginning of the LANSCE 2005 cycle, leading to a measurement of A_γ to 5×10^{-8}. Following this successful first measurement, the next step is to move the apparatus to a new beamline at HFIR, where the increased neutron flux and available beam time should enable the original sensitivity goal of NPDGamma to be reached.*

This request is similar to the recommendation of the Tribble Committee's Report of August 2003 [6].

> *The subcommittee urges that the initial tests and data collection be carried out for the asymmetry experiment during the next two running cycles at LANSCE and that the future of the experiment then be reevaluated.*

In October 2003, ORNL management expressed strong interest in hosting the experiment. A letter from Jim Roberto, the Associate Laboratory Director for Physical Sciences, and Glen Young, the Physics Division Director, stated

> *If the decision to move NPDGamma is made, we would be pleased to discuss the use of this cold-neutron beamline at HFIR by the NPDGamma collaboration. Given our prior discussions with you and your collaboration, we believe that the neutron fluxes on this beamline would be of considerable interest to you. We also believe the needed technical support and infrastructure resources for the experiment exist or can be arranged in a straightforward manner at ORNL. While we would need to discuss the time line and required resources for any move, we find the proposal to operate the NPDGamma experiment at HFIR to be an interesting and appropriate use of the beamline.*

After reviewing the case for moving NPDGamma to HFIR Jim Roberto agreed to allocate the beamline to the experiment for a year of running.

> *ORNL recognizes that the scientific merit of the NPDGamma experiment has been fully validated by numerous reviews including the Tribble Committee report. As a result, we feel that there is no need for further review of scientific merit to justify the allocation of the beam. Therefore, I am prepared to formally allocate the end position at HFIR CG4 for the NPDGamma experiment. The duration of this initial allocation remains to be negotiated, but it is our intention to allow sufficient beam time to obtain NPDGamma target statistical accuracy.*

Gene Henry wrote to the NPDGamma executive committee and emphasized the importance of getting a result at LANSCE. He indicated that only after a result was obtained at LANSCE would the DOE consider moving the experiment to a more intense source.

> *DOE's immediate interest is that return on the investment at LANL for this experiment be optimally maximized.Based on recommendations from the recent NSAC subpanel on fundamental neutron physics and your proposed Commissioning plan,the earliest that we would consider beginning a move from LANL to another facility would be in FY 2006. A case would need to be made for the best facility to which to move np to dgamma, taking into account the commitments made regarding an initial suite of experiments at the FNPB and available funding in the NP program.*

ORNL has begun design of a beamline for fundamental physics at HFIR. The beamline has been designed to accommodate the NPDGamma experiment. The neutrons/year delivered to the NPDGamma experiment are expected to be 25 times higher than at LANSCE. In a year of running at HFIR, the error in f_π^1 will be 7×10^{-8} or 2.5 times smaller than the statistical error from ^{18}F. ORNL and the University of Tennessee have recently hired Takeyasu Ito to lead the design and construction of the HFIR beam line project. The beamline is expected to be ready for the installation of the NPDGamma experiment in mid 2006.

We request the agencies and interested parties consider moving NPDGamma to HFIR.

D NPDGamma Proposal

Please see http://p23.lanl.gov/len/npdg/proposal/proposal.html

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